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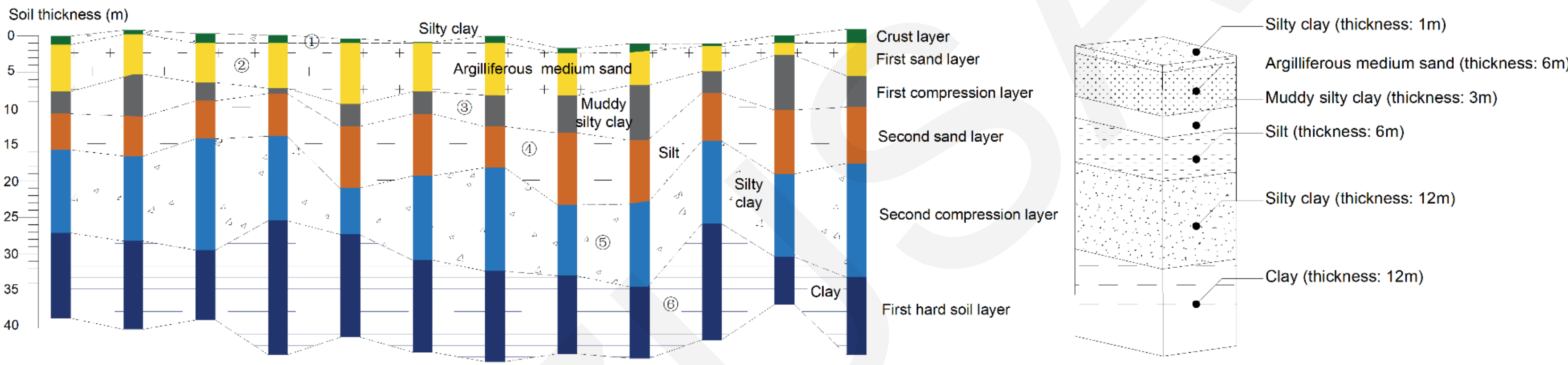
# Dynamic response of the ground beneath a high-speed railway based on typical upper Shanghai clays involving water table change

**Key words:** Dynamic response; Excess pore pressures; Water table rise; High-speed train; 2.5D finite element (FE) model

# TYPICAL UPPER SHANGHAI CLAYS



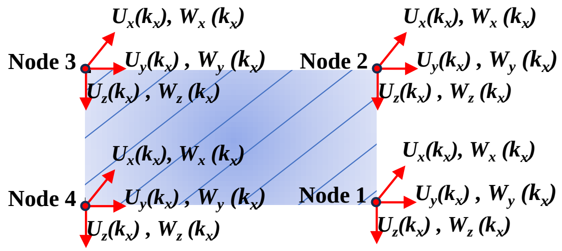

Schematic view of a typical soil layer distribution of upper Shanghai clays

- A rising water table increases soil water content, reduces soil strength, and amplifies vibrations under identical train loads, thereby posing greater risks to train operations.

- To investigate this phenomenon, we used a 2.5D finite element (FE) model of a coupled vehicle–embankment–ground system based on Biot’s theory. The ground properties were derived from a typical soil profile of the Yangtze River basin, using geological data from Shanghai, China.

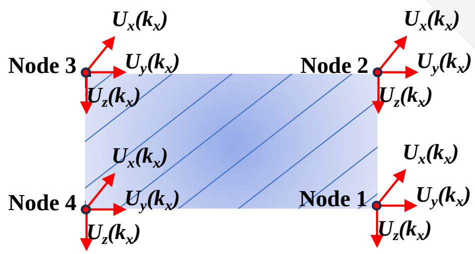
# SEMI-ANALYSIS SOLUTION METHOD AND NUMER-ICAL MODEL

- The widely adopted governing equations of Biot are used to describe the motion of embankments and ground under moving train loads. This approach enables the use of a 2.5D FEM to compute responses across the entire 3D space by evaluating responses in a 2D section for various wavenumbers.
- **Regarding changes in the water table, the region above it is treated as a single-phase medium.**



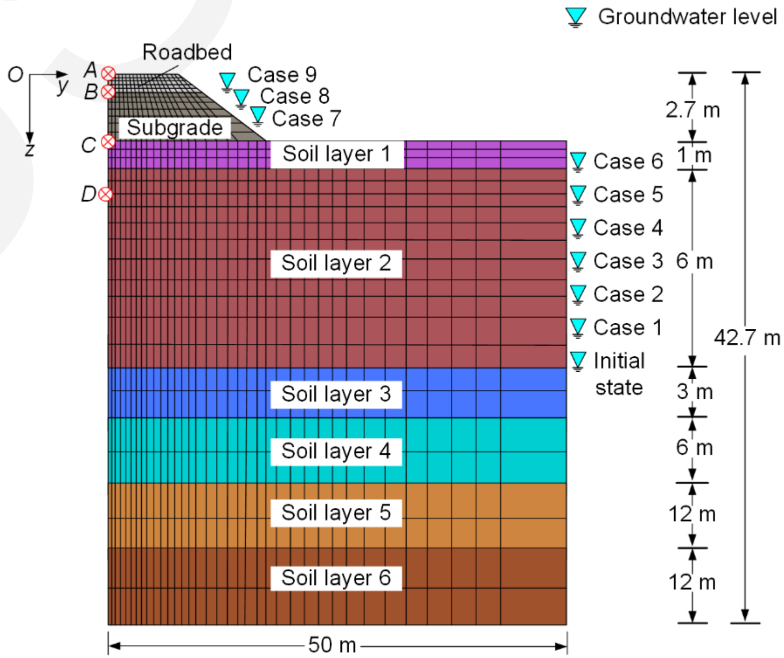

**Two-phase saturated medium**

The liquid phase parameters $\alpha$, $M$, $n$, $\rho_f$, $m$, $k_D$ are set close to 0




**Single-phase saturated medium**

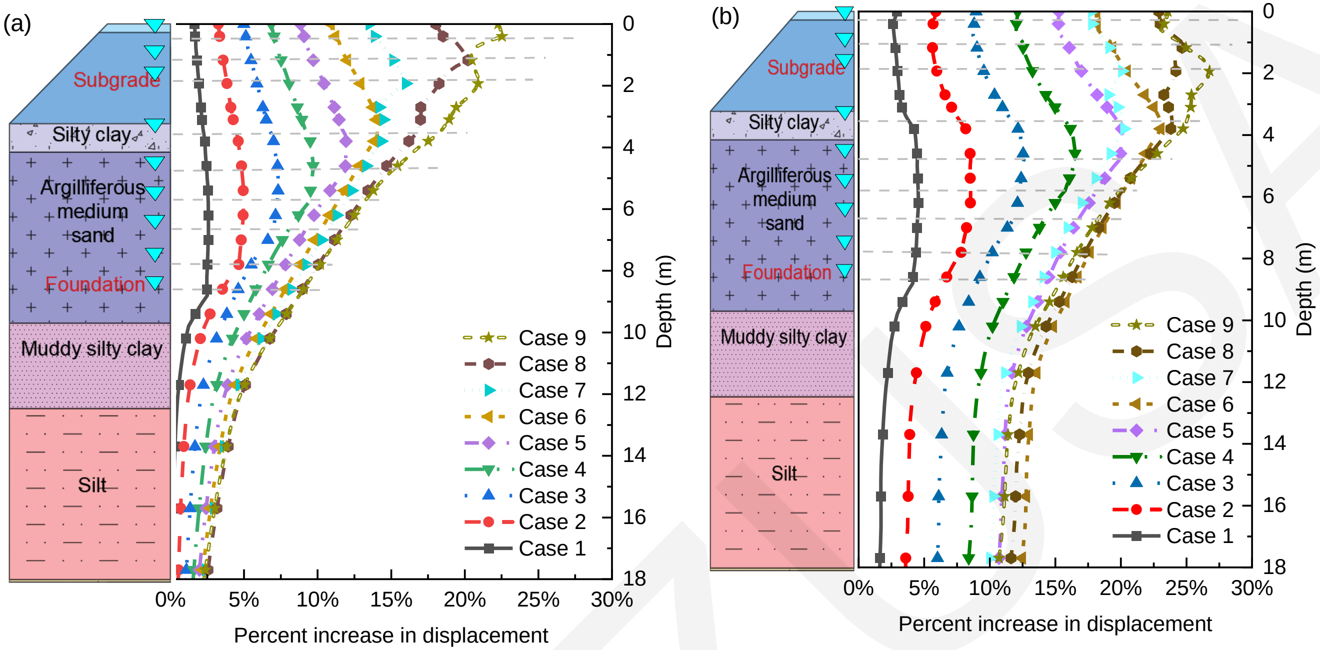
- Description of the two-phase saturated medium and sin-gle-phase medium in the 2.5D FE model



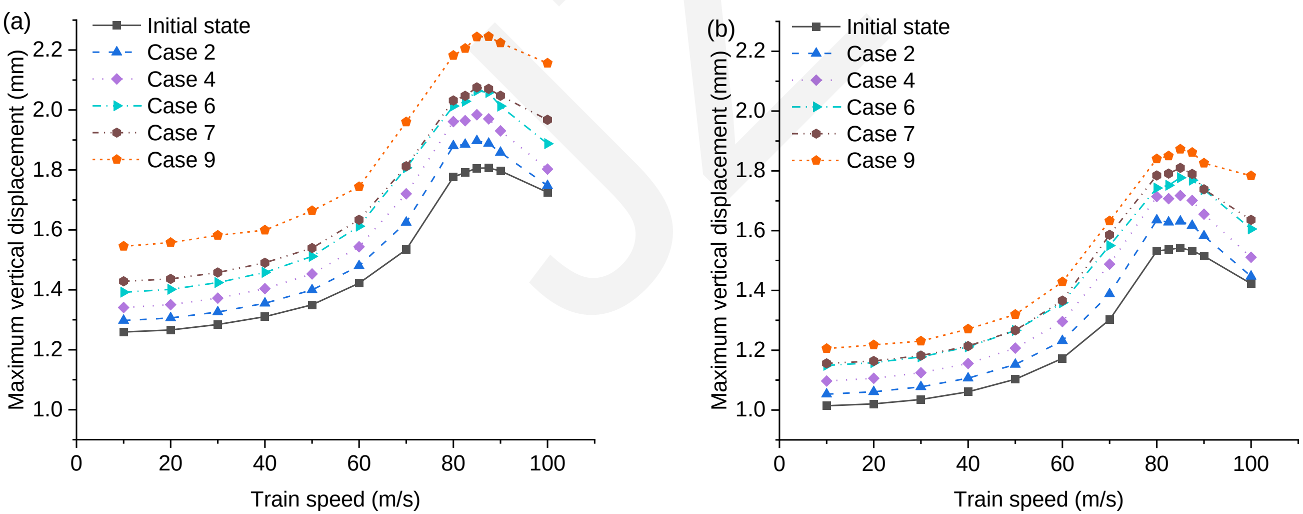

Schematic view of numerical model (not to scale)

# NUMERICAL ANALYSIS

- Vibration responses



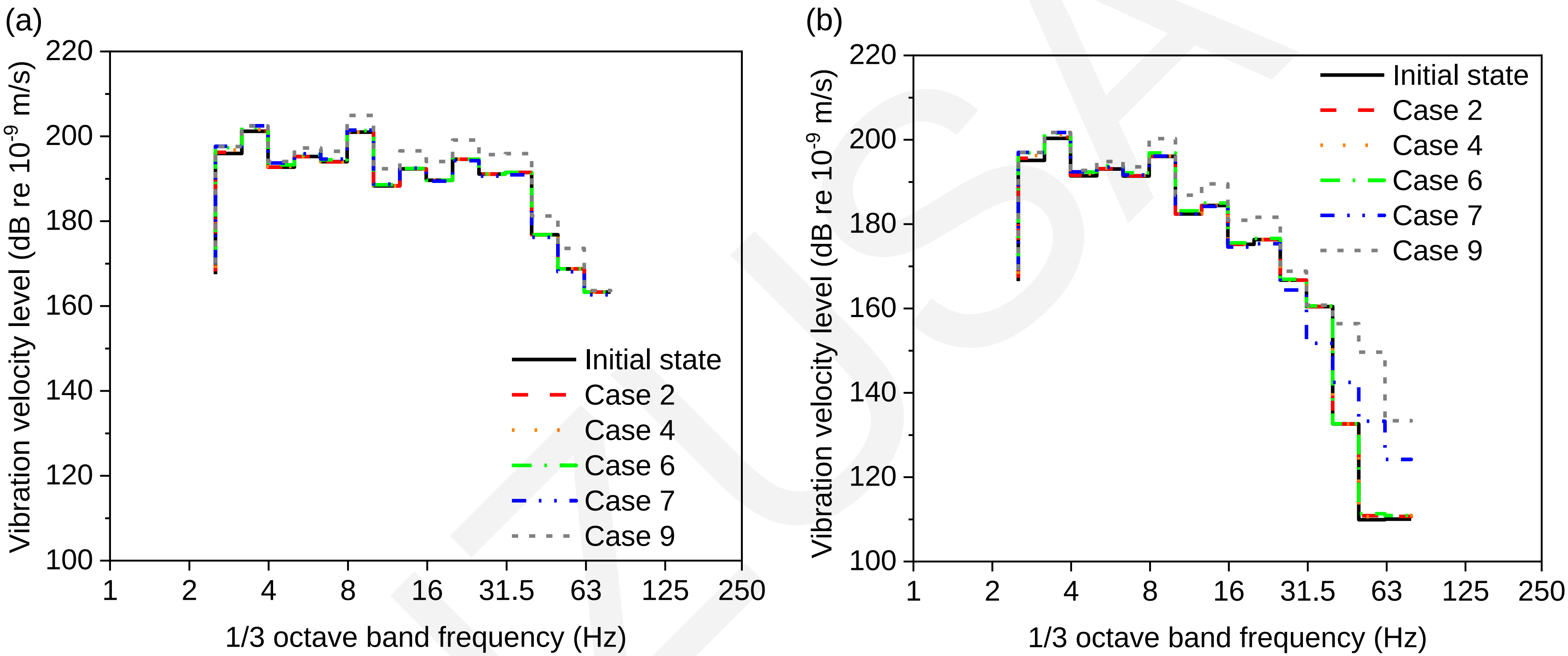

Percentage increases in dynamic displacement for each case plotted against depth: (a) 30 m/s; (b) 70 m/s




Dependence of maximum displacement responses on train speeds for different depths and cases: (a) point A; (b) point C

# NUMERICAL ANALYSIS

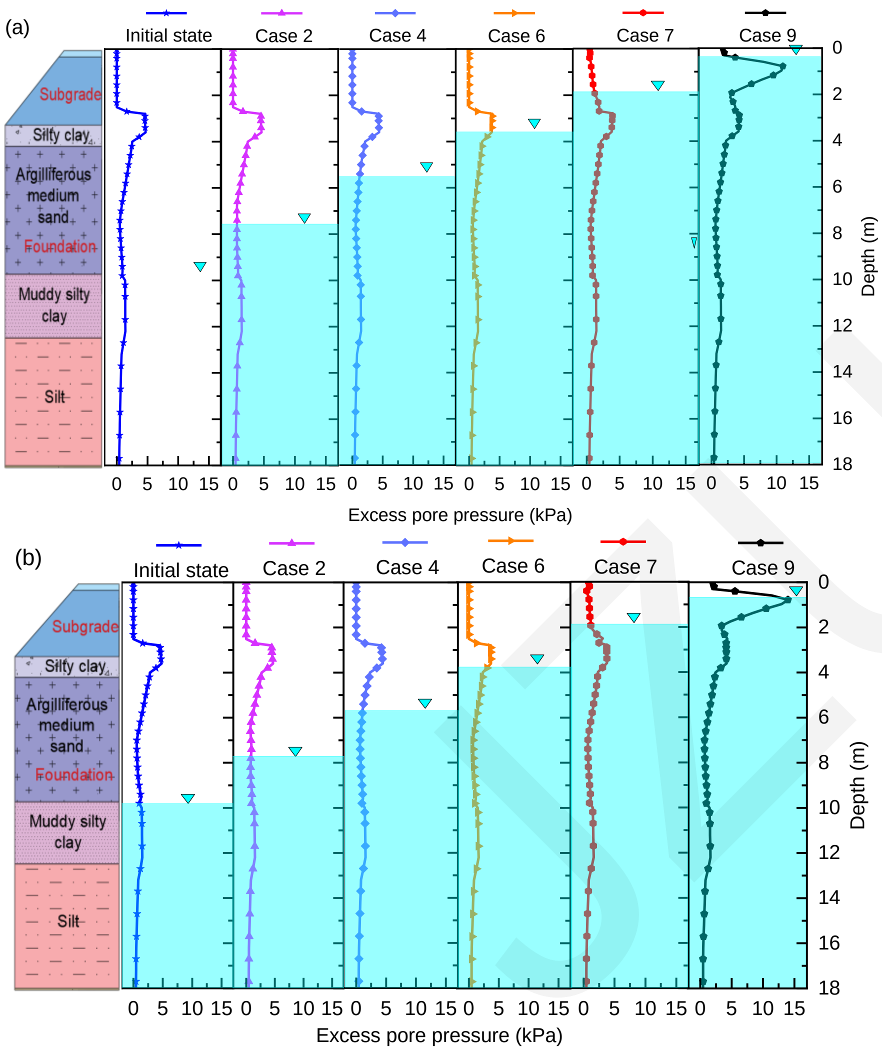
- Vibration responses



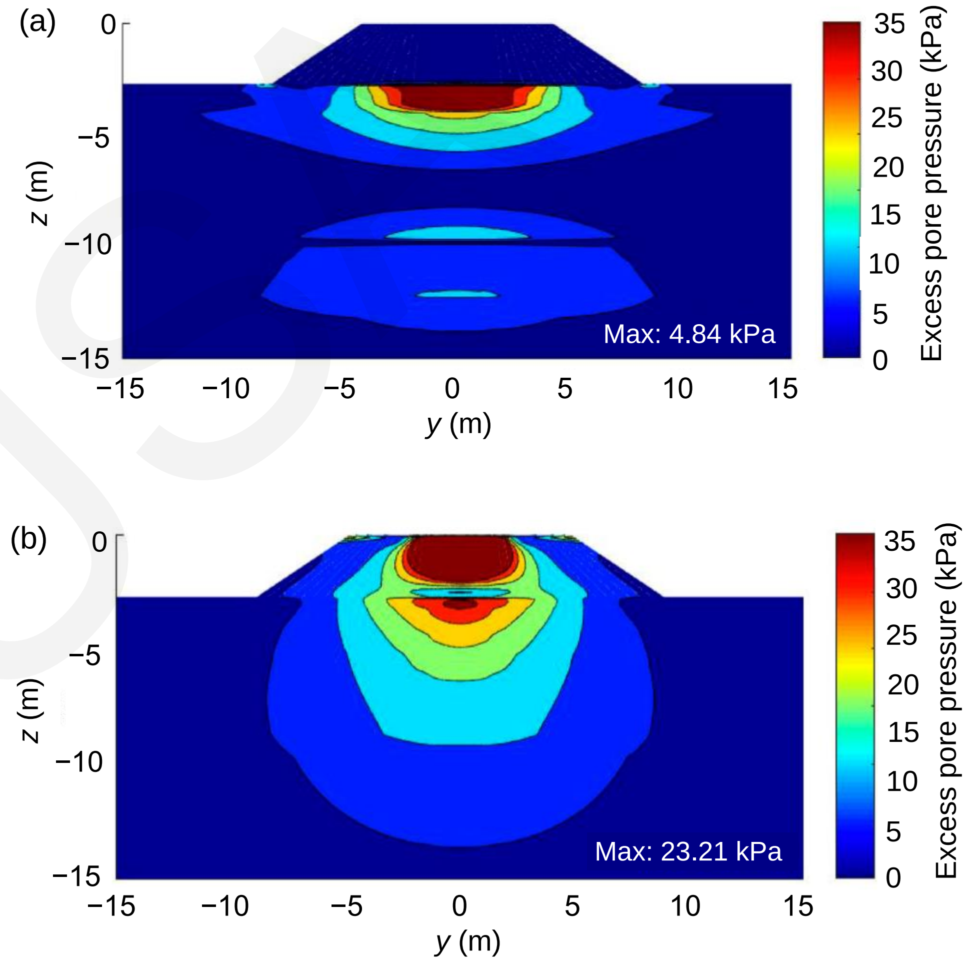

The 1/3 octave band frequency analysis under a train speed of 90 m/s: (a) point A; (b) point C

# NUMERICAL ANALYSIS

- Excess pore pressure responses



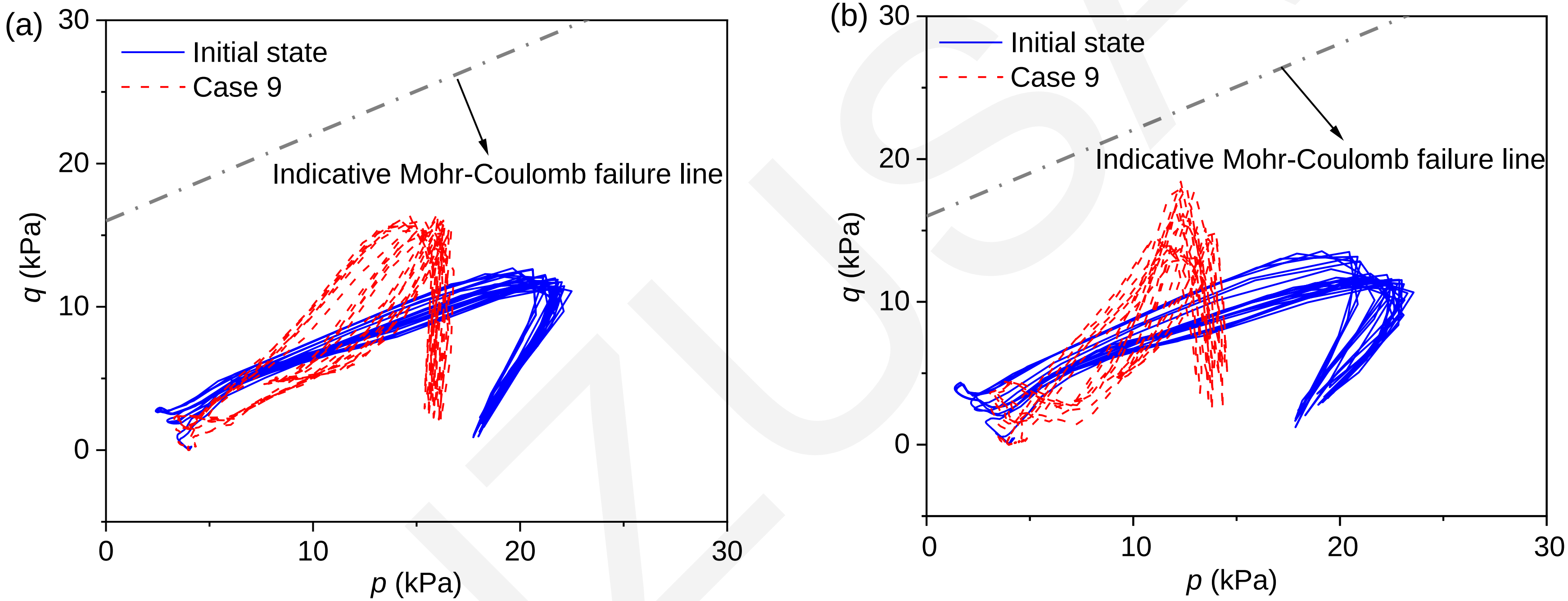

Maximum excess pore pressures versus depth: (a) 30 m/s; (b) 70 m/s




Excess pore pressure distribution contours of different cases in the y-z plane at 70 m/s: (a) initial state; (b) Case 9. References to color refer to the online version of this figure

# NUMERICAL ANALYSIS

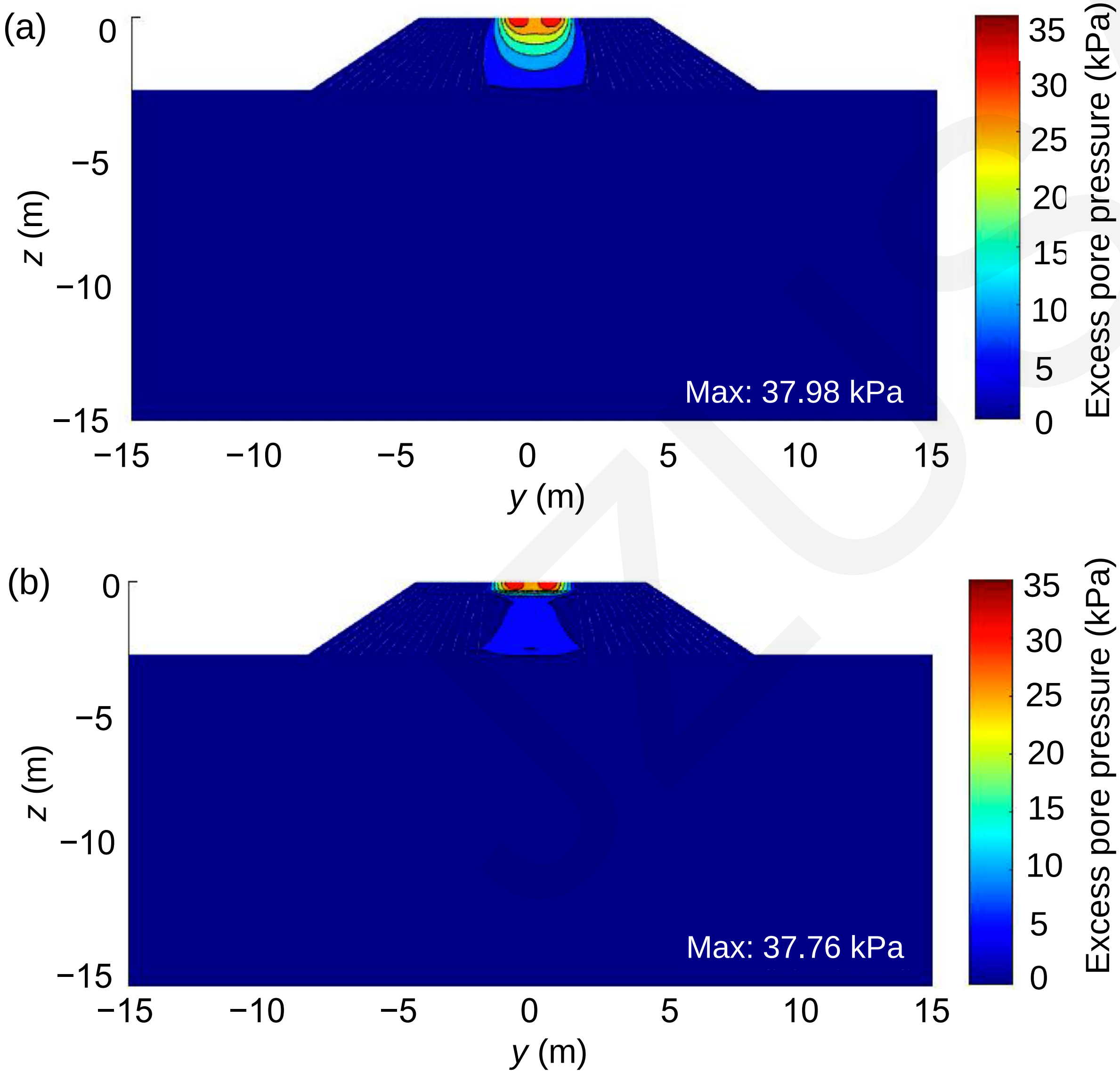
- Effective stress analysis




Effective stress path at point B under different train speeds: (a) 30 m/s; (b) 70 m/s

# NUMERICAL ANALYSIS

- Effective stress analysis




Contours of maximum effective stress for different cases in the y-z plane at 70 m/s: (a) initial state; (b) Case 9

# RESULTS AND CONLUSIONS

- 1. The rise in the water table amplifies the track's dynamic displacement. This increase in dis-placement amplitude is not confined to the depth of the water table change but affects the entire em-bankment–foundation cross-section. This amplifica-tion effect intensifies with higher train speeds.
- 2. For a high-speed railway built on typical upper Shanghai clays, the critical speed is around 85 m/s. While the rise in the water table significantly increases the displacement amplitude, it has minimal impact on the critical speed.
- 3. The vibration frequency of the embankment and foundation is influenced mainly by the length of the train carriage and the adjoining bogies. These dominant frequencies remain consistent across dif-ferent water tables for both the subgrade and the ground foundation.
- 4. The higher the train speed, the deeper the position at which the peak ex-cess pore pressure appears. When the water table rises within the subgrade, the peak values of excess pore pressure increase.
- 5. The rise in the water table within the subgrade has a more pronounced effect on the dynamic re-sponse of the embankment than on the ground foundation. When the water table rises into the sub-grade, significant excess pore pressure is generated within the embankment. This condition brings the stress path closer to the indicative Mohr-Coulomb failure line, increasing the likelihood of soil failure in the subgrade.